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Performance Analysis of Hotel Lighting Control System

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Background

Lawrence Berkeley National Laboratory (LBNL), the Sacramento Municipal Utility District (SMUD), DoubleTree Hotels, and The Watt Stopper, Inc., formed a partnership to study a new energy-efficient lighting control system under the PIER Lighting Research Program. This report describes the details and results of this study, which had the objective of evaluating the performance of this new lighting control system.

The new Lighting Control System (LCS) is a wall switch occupancy sensor that has been designed specifically for hotel environments to save energy while providing users a higher level of lighting amenity. The LCS has two key features that make it ideally suited for placement in hotel guestroom bathrooms. The first feature is that the LCS is preprogrammed with a timeout setpoint that is significantly longer than what is typically used by occupancy sensors. Findings from prior research conducted by LBNL and The Watt Stopper, Inc. suggested that most of the energy used by hotel bathroom luminaires is from the relatively infrequent periods when they are left on for very long periods of time (i.e. greater than four hours). By utilizing longer timeout setpoints (one hour for the LCS), these long periods can be eliminated while greatly minimizing the chances of generating “false offs” in which the lights turn off when there is a guest in the bathroom.

The second key feature of the LCS is a built-in LED nightlight that automatically turns on whenever the bathroom luminaire is turned off. Prior research also suggested that a small but significant amount of the extended period usage of the bathroom luminaires occurred during nighttime hours. It is thought that these periods represent the hotel guests purposely leaving the bathroom luminaire on as a nightlight when they retire for the evening. The nightlight feature of the LCS has the potential to provide adequate illumination for guests to navigate at night while using only a fraction of the energy of the bathroom luminaire.

LBNL researchers measured the lighting use in 15 guest bathrooms in the DoubleTree Hotel in Sacramento, California over an eight-month period gathering a minimum of two months of pre-retrofit LCS (baseline) and two months of post-retrofit LCS data from each room. The test and analysis was conducted to identify the practical advantages and disadvantages of using this system. The quantitative methodologies used to evaluate the new LCS prototypes include:

- A comparison of average lighting energy consumption between pre- and post- retrofit LCS.

- A comparison of the usage pattern between pre- and post-retrofit LCS, showing how the LCS changes the usage pattern and optimizes the energy consumption.

Test Plan

The following section describes the steps taken to identify the practical advantages and disadvantages of using this system. This includes the selection of test rooms, data collection for the baseline condition, installation of the LCS devices, and data collection of the post-LCS condition.

1. Choose representative hotel rooms

It was considered critically important to the study to select test rooms that were both representative of the hotel as a whole as well as more generally considered “typical” hotel rooms. Part of the criteria for selecting the DoubleTree Hotel in Sacramento as the test site was that it was considered to contain a wide variety of typical rooms. The hotel was built in the 1970s in several phases and consequently its bathroom layouts and fixtures vary widely throughout the hotel. It is mainly a business hotel, but 25 percent of the rooms are rented long term by an airline and are used for flight crews to take a rest. These factors may affect the test results, in that 1) different layouts may affect the user’s preference and 2) flight crews have different schedules than ordinary travelers. Considering these factors, LBNL selected 15 rooms that cover different conditions (different bathroom layouts, and flight crew/no flight crew occupancy), so that the results of this study could be more widely applied.

2. Install data-logging equipment

LBNL researchers went to the DoubleTree Hotel to initialize and install Hobo light state loggers. These loggers are installed close to the luminaires and take a record every time the lights are switched on or off. These loggers needed to be carefully installed and calibrated in order to be sensitive enough to register the switching of the bathroom luminaire, but not so sensitive as to register the usage of other lighting in the area, such as heat lamps that were present in many of the spaces. The loggers can hold a maximum of 2007 data points, which normally represents about four months of data. The data can then be downloaded into a text file to be analyzed. Table 1 shows a sample of the Hobo light state logger output data.

Table 1: Sample output from Hobo light state loggers

Date	Time	OFF (0) / ON (1)
10/04/02	18:59:59.5	ON
10/04/02	19:24:43.5	OFF
10/04/02	22:10:25.0	ON
10/04/02	22:23:41.0	OFF
10/05/02	05:38:39.0	ON
10/05/02	08:23:17.5	OFF
10/05/02	13:10:01.0	ON
….		

The majority of the rooms were fit with one single logger. However, in five rooms three loggers were installed. This was done to ensure the accuracy of the loggers by allowing for data crosschecking between the various loggers.

3. Baseline data collection

After the loggers were installed for at least two months, LBNL researchers went to the DoubleTree Hotel to download the data from the loggers. These data represent the baseline data without the LCS. The loggers were then reinitialized and relaunched in anticipation of data collection of the post-LCS period. (For data logging periods in which the loggers recorded both baseline and post-LCS data, the data files were manually parsed at the end of the logging period based on the installation date of the LCS.)

4. Install Lighting Control System (LCS)

After downloading the baseline data, the LCSs were installed by the DoubleTree Hotel engineering staff. The installation process involved removing the existing bathroom luminaire wall switch and wiring in the LCS in its place. These installations generally took about 15 minutes each. The LCSs were preprogrammed with the 1-hour timeout set point and thus needed no additional programming during installation.

5. Post-LCS data collection

After the loggers operated for an additional two months following installation of the LCS, LBNL researchers again went to the DoubleTree Hotel to download the data from the loggers. These data are the post-LCS data.

Quantitative Methodologies

The LCS functions as an energy saving device. It saves energy by reducing the time of operation of the bathroom luminaires. The energy savings (Watt-hours) generated by the LCS is simply the product of the reduction in time of usage (hours) with the load of the bathroom luminaires (Watts). In the performance analysis, LBNL focused on the reduction in time of use instead of the energy savings. By using time instead of energy, the analytical results can be applied more generally to other hotels that have bathroom luminaires of differing wattages.

The initial analysis step upon downloading data from the loggers was the verification of data accuracy. This analysis was done in a number of different ways, including cross-checking with other loggers at that location when possible and comparing the usage patterns to those of other similar situations when cross-checking was not possible.

The process of collecting data from the field and reducing it to meaningful parameters (such as average time usage and usage profiles) included the following steps:

1. Average lighting energy consumption comparison

The total time the luminaires are left on per day was calculated for each day of logging for every room logged. These totals could then be further sorted and/or averaged to provide "average" or typical usage information. The data for the baseline and post-LCS conditions are tabulated separately, as illustrated in Table 2.

Some of the specific steps for these calculations included the following:

a) **Burning Hours** for each room on each day**:** The raw data have records for each time the light was turned on or off (see Table 1). The time between each pair of ON and OFF readings represents an interval that the light was on. Subtracting the ON time from the OFF time yields the interval length. Generally, there are several such intervals in each day and the sum of these interval lengths is the burning hours for that day. For the intervals across two days, say from 11 p.m. on 10/05/02 to 2 a.m. on 10/06/02, the data were parsed at midnight into two pieces, with the time segment prior to midnight added to the first day and the time segment after midnight added to the second day.

b) **Average Burning Hours (ABH)** for each room: The daily burning hours (from step a) can then be used to calculate the average burning hours over the test period for each room. For example, if the test lasted 60 days, the sum of the 60 daily burning hours divided by 60 yields the ABH for the room.

Table 2: Data Table for Average Burning Hours for Baseline and Post –LCS Periods for Each Room Tested

		Room#1	Room#2	……
Baseline	Average Burning Hours	4:45:05	6:15:57	
Post - LCS	Average Burning Hours	4:09:48	4:01:37	
10/04/02		0:18:10	10:53:10	
10/05/02		7:04:34	2:13:21	
10/06/02		8:17:55	1:55:14	
10/07/02		0:42:22	8:50:15	
10/08/02		3:11:01	5:57:46	
10/09/02		11:05:14	1:53:10	
10/10/02		9:33:54	3:33:34	
10/11/02		10:50:05	0:00:00	
……				

2. Usage pattern comparison

Three different usage pattern profiles were constructed to assess the energy savings opportunities of the LCS in the hotel bathroom environment. The first profile sorts the data to identify the length of operation of the bathroom luminaire for each time it was turned on. The second profile sorts the data to identify the percentage of total energy that the luminaire consumes as represented by usage periods of various durations. This helps determine the setpoint for the LCS and allows for an estimate of expected energy savings at various set points. The final usage pattern profile sorts the data to determine, on average, when and how much the luminaires are typically used. This profile gives a broader overall picture of the daily usage dynamics and trends in this application. This usage pattern also allows for the identification of the correspondence between the bathroom luminaire's usage and utility peak load conditions.

2.1 Frequency and Total Time Analysis

a) **Burning length** for each use. In the raw data, each pair of ON and OFF represents a use. Subtracting the ON time from the OFF time is the burning length for the use.

b) **Group the result into bins**: Each use period is placed in a bin based on the burning length. For example, the burning lengths falling between one hour and two hours are in one bin; burning lengths falling between two hours and four hours are in another bin, etc.

c) **Frequency and Total Time** for each bin**:** For each bin, the burning lengths are summed. The number of entries in each bin is called the frequency. The sum of the burning lengths in the bin is the total time. For example, in the one to two hours bin, there may be 50 time uses (frequency), the sum of which might be 78 hours (total time).

d) **Percentage of Frequency and Total Time** for each bin. The percentage of the frequency and total time represented by each bin is calculated by dividing the results for that bin by the results for the entire logging period. For example, if the one to two hours bin has frequency of 50 while the total frequency of all of the bins is 500, then this bin has percentage of frequency = 50/500*100% = 10%. If the one to two hours bin has total time of 78 hours and the total burning hours of all of the bins is 1000 hours, then this bin has percentage of total time = 78/1000*100% = 7.8%.

e) These calculations are repeated for both the baseline and post-LCS data sets.

f) Finally, these data can be charted. See Tables 3-4 and Figures 1-2.

Table 3: Example Data of Frequency and Total Time Data for the Baseline Period

Baseline

Group	Total Time	Frequency	Total Time (percentage)	Frequency (percentage)
0:00:04	0:00:00	0	0.00%	0.00%
0:00:08	0:03:44	34	0.00%	1.60%
0:00:16	0:15:40	78	0.01%	3.66%
0:00:32	0:40:32	102	0.03%	4.79%
0:01:00	2:20:41	183	0.10%	8.59%
0:02:00	6:50:53	285	0.29%	13.37%
0:04:00	10:50:27	224	0.46%	10.51%
0:08:00	22:25:27	232	0.95%	10.89%
0:16:00	42:39:07	223	1.80%	10.46%
0:32:00	79:36:05	207	3.36%	9.71%
1:00:00	117:38:43	158	4.96%	7.41%
2:00:00	186:07:16	132	7.85%	6.19%
4:00:00	321:14:42	113	13.55%	5.30%
8:00:00	436:52:40	76	18.43%	3.57%
16:00:00	653:27:49	61	27.56%	2.86%
More	489:38:20	23	20.65%	1.08%
Total	2370:42:06	2131	100%	100%

Table 4: Example Data of Frequency and Total Time Data for the Post-LCS Period

Post-LCS

Group	Total Time	Frequency	Total Time (percentage)	Frequency (percentage)
0:00:04	0:00:00	0	0.00%	0.00%
0:00:08	0:01:13	11	0.01%	2.66%
0:00:16	0:03:18	17	0.01%	4.11%
0:00:32	0:07:14	20	0.03%	4.83%
0:01:00	0:27:19	35	0.11%	8.45%
0:02:00	1:02:48	44	0.26%	10.63%
0:04:00	1:08:45	26	0.28%	6.28%
0:08:00	3:58:33	40	0.98%	9.66%
0:16:00	9:46:12	44	2.41%	10.63%
0:32:00	12:10:52	29	3.01%	7.00%
1:00:00	25:45:01	36	6.36%	8.70%
2:00:00	87:24:31	63	21.60%	15.22%
4:00:00	90:17:26	31	22.32%	7.49%
8:00:00	56:05:04	11	13.86%	2.66%
16:00:00	34:32:20	3	8.54%	0.72%
More	8:44:41	4	2%	0.97%
Total	404:35:17	414	100%	100%

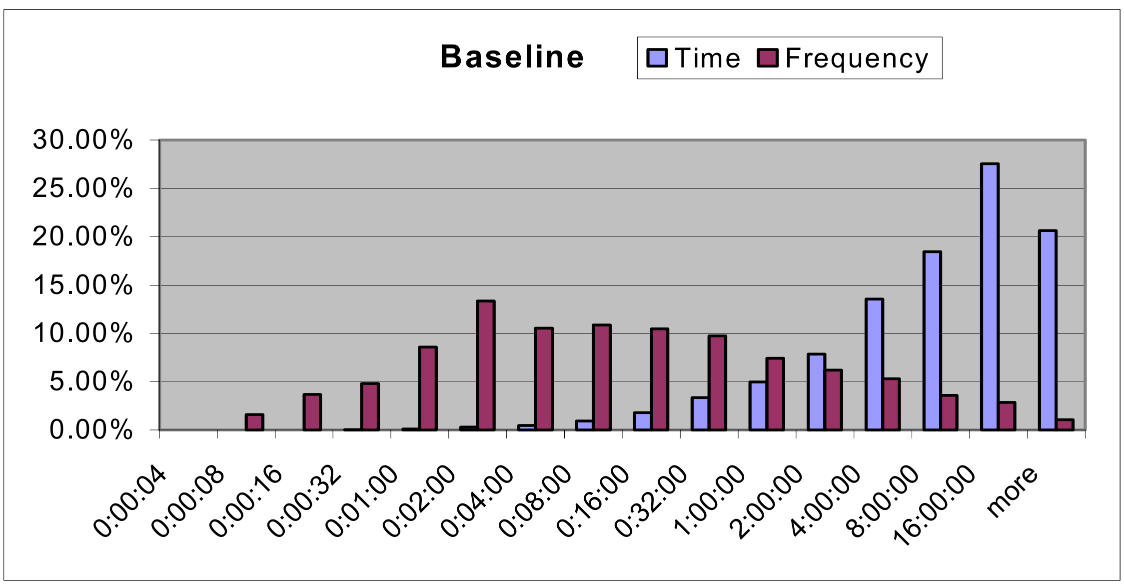

Figure 1: Example Chart of Frequency and Total Time Data for the Baseline Period

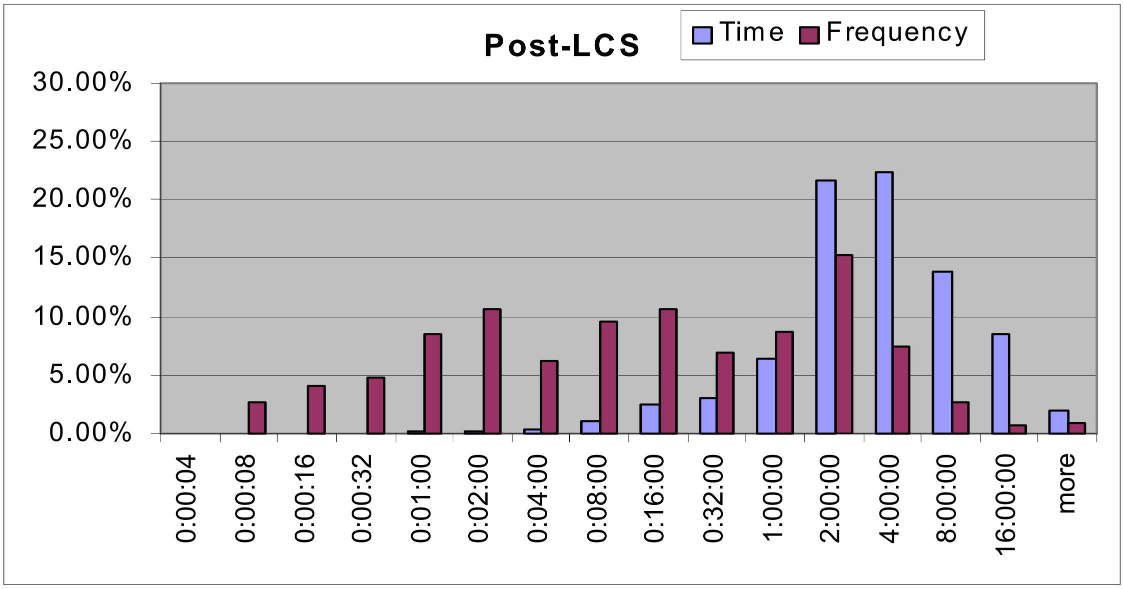

Figure 2: Example Chart of Frequency and Total Time Data for the Post-LCS Period

2.2 Usage Pattern as a Function of the Time of Day

a) **Checkpoints**: A number of check points throughout a day are chosen, such as at the beginning of each hour, 1:00, 2:00, … , 24:00. Given a large enough overall data set, the greater the number of checkpoints used, the greater the precision of the usage pattern displayed.
b) **Light ON/OFF** at each checkpoint: Every day in the logging period is checked to see if the light was on or off at each of the checkpoints.
c) **Percentages**: For each checkpoint, the percentage of days in which the light was on in the test period is calculated. For example, if the test lasted for 60 days, and on 15 days the light was on at 8 a.m., then the percentage for 8 a.m. is 15/60 *100% = 25%.
d) These calculations are repeated for both baseline and post-LCS data sets.
e) Finally, these data can be charted. See Table 5 and Figure 3.

Table 5: Example Data of Baseline and Post-LCS Data as a Function of the Time of Day

Check Points	Room 1		Room 2	
	Baseline	Post-LCS	Baseline	Post-LCS
0:00	12.82%	4.40%	16.67%	8.79%
1:00	10.26%	2.20%	12.82%	7.69%
2:00	8.97%	3.30%	12.82%	5.49%
3:00	7.69%	1.10%	11.54%	6.59%
4:00	6.41%	0.00%	11.54%	3.30%
5:00	7.69%	2.20%	11.54%	4.40%
6:00	14.10%	0.00%	16.67%	9.89%
7:00	20.51%	7.69%	29.49%	21.98%
8:00	23.08%	8.79%	20.51%	32.97%
9:00	23.08%	4.40%	15.38%	25.27%
10:00	24.36%	9.89%	17.95%	16.48%
11:00	19.23%	3.30%	21.79%	20.88%
12:00	16.67%	5.49%	11.54%	18.68%
13:00	14.10%	5.49%	15.38%	19.78%
14:00	5.13%	7.69%	16.67%	19.78%
15:00	6.41%	6.59%	16.67%	18.68%
16:00	11.54%	7.69%	7.69%	19.78%
17:00	8.97%	2.20%	11.54%	14.29%
18:00	15.38%	5.49%	7.69%	18.68%
19:00	14.10%	5.49%	11.54%	17.58%
20:00	14.10%	4.40%	12.82%	15.38%
21:00	12.82%	6.59%	12.82%	19.78%
22:00	10.26%	5.49%	12.82%	14.29%
23:00	14.10%	4.40%	12.82%	10.99%

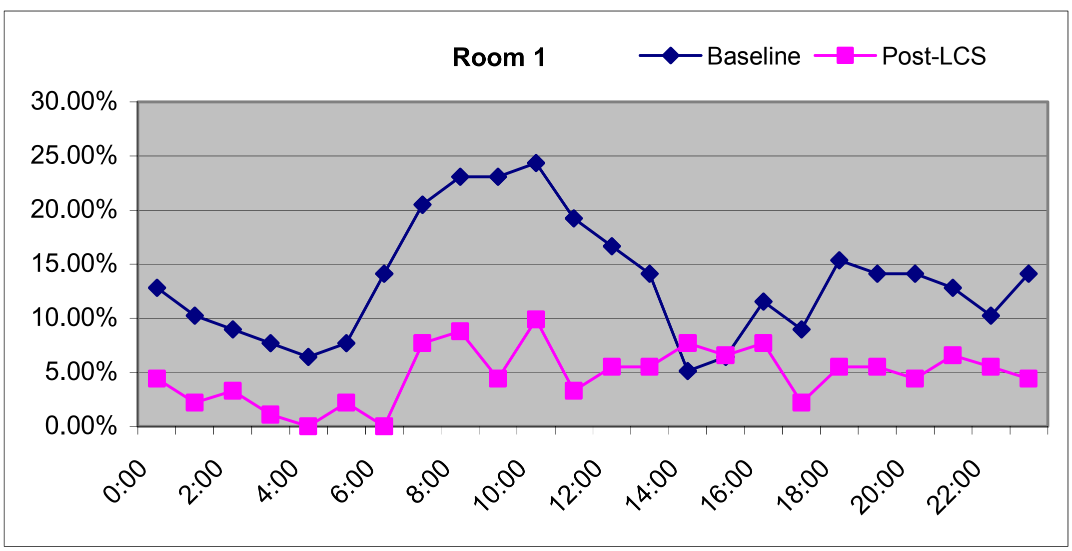

Figure 3: Example Plot of Baseline and Post-LCS Data as a Function of the Time of Day

Performance Analysis

Five of the 15 original test rooms were logged with redundant loggers. These five rooms each had three loggers measuring the bathroom luminaires during testing, allowing for a cross comparison of data. While most of the data from the 10 rooms with single loggers appeared to be valid, some of them clearly had errors. This led to a decision to base the overall analysis of the LCS on data gathered from the five rooms with redundant loggers. This decision was based primarily on the facts that 1) it was very difficult to separate valid from invalid data in the single logger rooms with a high level of certainty and 2) the data from the five redundant rooms provided a statistically significant data set. Therefore, the analysis presented below is based on data just from these five rooms. For the purposes of gathering as many data points as possible and to ensure uniformity between the test rooms during the study, these five rooms were kept at near 100 percent occupancy during the study.[1]

It should be stressed that while the analysis was limited to data from these five rooms, the overall data set is still very large. It is also important to note that monitoring hotel rooms is very different from monitoring other types of spaces because the occupants change so frequently. The real "sample" in this study is not the number of rooms but the number of room-days or occupant-days. Since all five of the rooms were monitored for at least two months in both baseline and post-LCS cases, data from these rooms represent over 300 room-days (5 rooms * 60 days) of data. Additionally, as the average stay in a business hotel is one to two days, the data collected represent the usage patterns of approximately 400 unique guests (or data points) over the duration of the test. To get a statistically significant sample, researchers like to typically get 30 to 60 independent data points.

Using the methods described in the quantitative methodologies section of this report, LBNL sought to answer the following questions.

- What is the average burning hours per day before and after installation of the LCS?
- To what extent does the LCS eliminate the long burning periods?
- To what extent does the reduction in long burning periods contribute to energy savings?
- How does the LCS change the usage profile as a function of time of day?

Answering these questions should give an initial indication of the effectiveness of the LCS and perhaps provide broader insights into the potential usefulness of the device.

1. Average burning hours per day

Table 6 shows the average usage data. The average burning hours per day for each of the five rooms were between four and five hours before installation of the LCS, while this number

[1] The overall effect of occupancy rates on the energy savings of the LCS will be touched on further in the analysis later in this report.

decreased to 1.5 to three hours after installing the LCS. In an "average" room, the luminaires were generally left on for 4.4 hours every day without the LCS, while this number decreased to about 2.4 hours with the LCS. The overall reduction is 46.5 percent.

Table 6: Average burning hours per day

Room #	Average	210	215	242	588	616
Hours - baseline	4:25:33	4:09:54	4:30:27	4:18:35	5:00:17	4:08:33
Hours - post-LCS	2:22:02	3:00:02	2:22:19	2:12:43	1:30:48	2:44:17
Reduction (%)	46.5	28.0	47.4	48.7	69.8	33.9

2. Usage profile as a function of time of day

Figure 4 looks at the same set of data and shows when, on average, the bathroom luminaires were operated during both the baseline and the post-LCS periods. Both cases experience peak usage in the morning, but the LCS reduced both the amplitude and duration of this peak. In the evening, the usages for the post-LCS are less than half of the baseline; after midnight the usages for the post-LCS cases were reduced even more, as they approached zero. During the peak load period, from noon to 6pm, an average of approximately 40 percent energy savings was obtained.

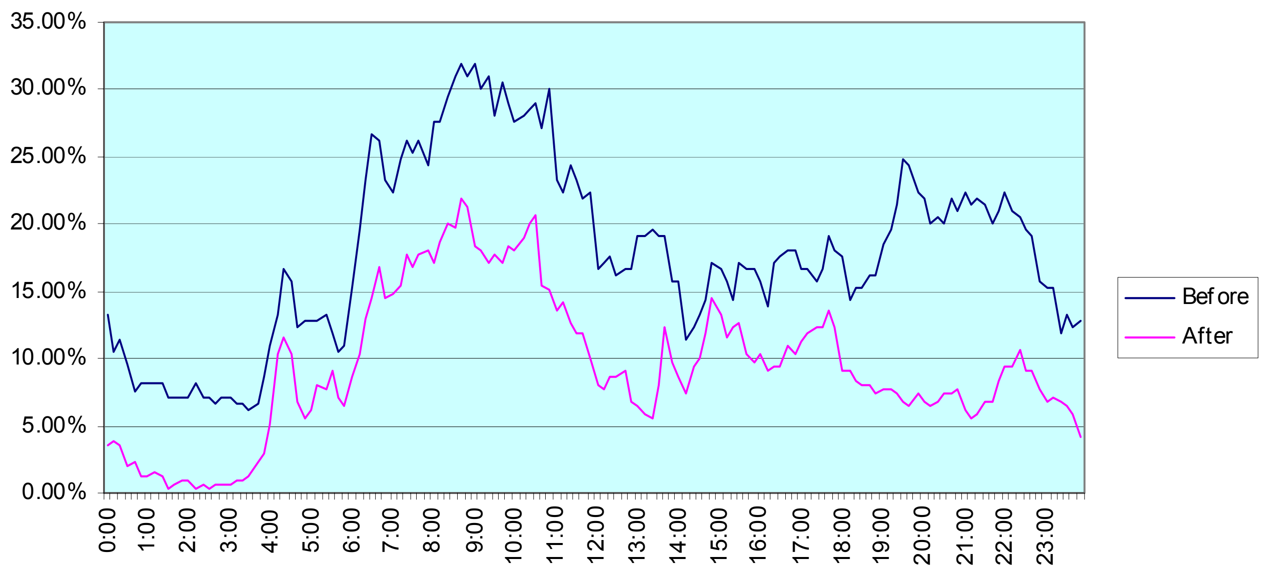

Figure 4. Usage profile as a function of the time of day

3. Reduction of long burning uses

The LCS saves energy by reducing the time of operation of the bathroom luminaires. With its preprogrammed timeout set to one hour, the LCS should eliminate most of the long-burning uses, which, although infrequent, consumed a significant amount of energy. Figure 5 presents a comparison of the usage pattern profile that demonstrates the length of burning for each use. It shows, on average, how frequently the luminaires were used for a given length of time each day.

For example, the bars for 0:16:00 indicates that the luminaires on average are turned on greater than 16 minutes and less than 32 minutes for only 0.62 times per day. Interesting points demonstrated by Figure 5 are:

- Uses with burning lengths greater than 2.5 hours were reduced significantly by the LCS. Eighty percent of the uses falling in this interval were eliminated. The number of uses per day with durations greater than 2.5 hours were changed from 0.50 to 0.10, a reduction of 0.40.
- Uses with burning lengths between one hour and 2.5 hours increased. The number of uses in this interval was changed from 0.47 to 0.88, an increase of 0.41, which was approximately the reduction from 2.5+ hours. Intuitively, this is a direct effect of the LCS cutting the long burning uses into shorter ones.
- Uses with burning lengths up to one hour decreased slightly. This is an interesting finding because uses less than one hour should not have been affected by the occupancy sensors timeout of one hour. One possible explanation of this result is that the night light on the LCS provides enough light for some functions allowing the user, on average, to turn on the bathroom luminaire less frequently.
- The average number of uses per day can be found by adding up all the bins in Figure 5. This results in a finding that the baseline has an average of five uses a day while the LCS yields an average of four uses a day. This result goes against conventional wisdom that occupancy sensors tend to increase the number of switches encountered by a luminaire, but does seem consistent with the theory above that the presence of the nightlight may at times eliminate the number of uses of the bathroom luminaire. Although this finding has little effect on the energy consumption, it shows an unexpected usage pattern change caused by the LCS, which may actually suggest a further maintenance advantage as a reduced number of switches a day should have a positive impact on lamp life.

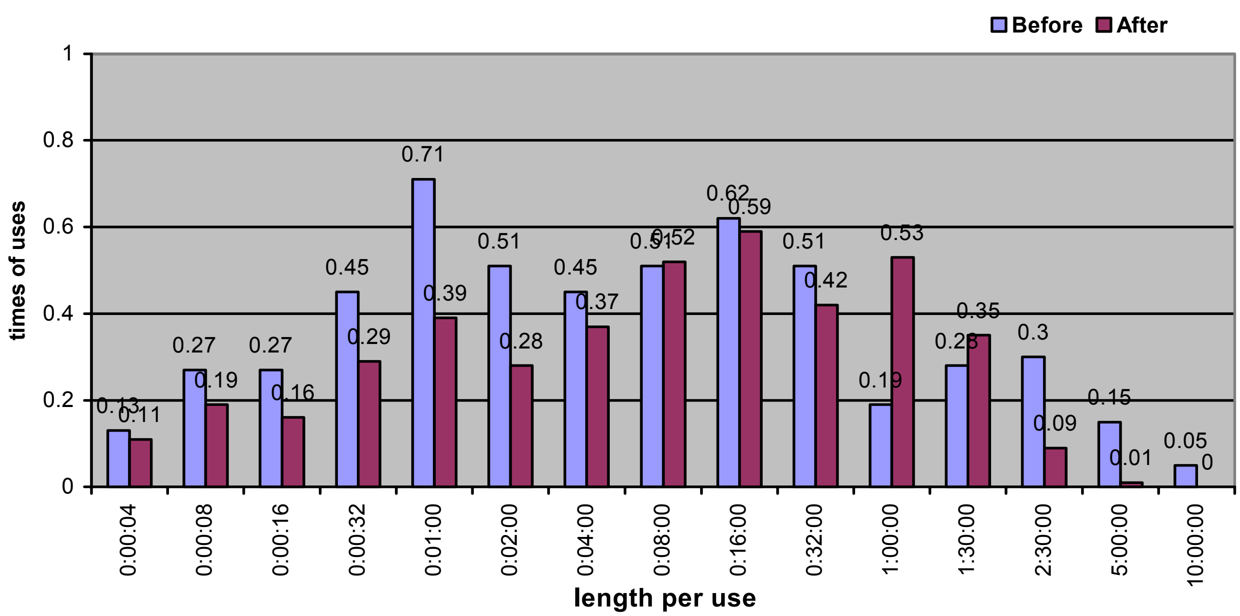

Figure 5. Frequency on an average day

4. Energy saving benefit from reduction of long burning uses

Findings from prior research conducted by LBNL and The Wattstopper, Inc. suggested that most of the energy used by hotel bathroom luminaires is from the relatively infrequent periods when the luminaires are left on for very long periods of time. This result was reinforced by the current data. Figure 6 shows the frequency and energy used for the given length of burning before installing of the LCS. The frequency has a similar meaning as in Figure 5, except Figure 6 data is presented as a percentage instead of an absolute number. The total time represents the percentage that the ON periods from each time interval contributed to the total operating time of the luminaire. The energy usage is directly related to the total time, as it is merely the product of the total time and the wattage of the luminaire. Figure 6 shows that while the bathroom lights are left on for longer than 2.5 hours only 9.5 percent of the time, these longer burning periods account for 65 percent of the fixture's energy consumption.

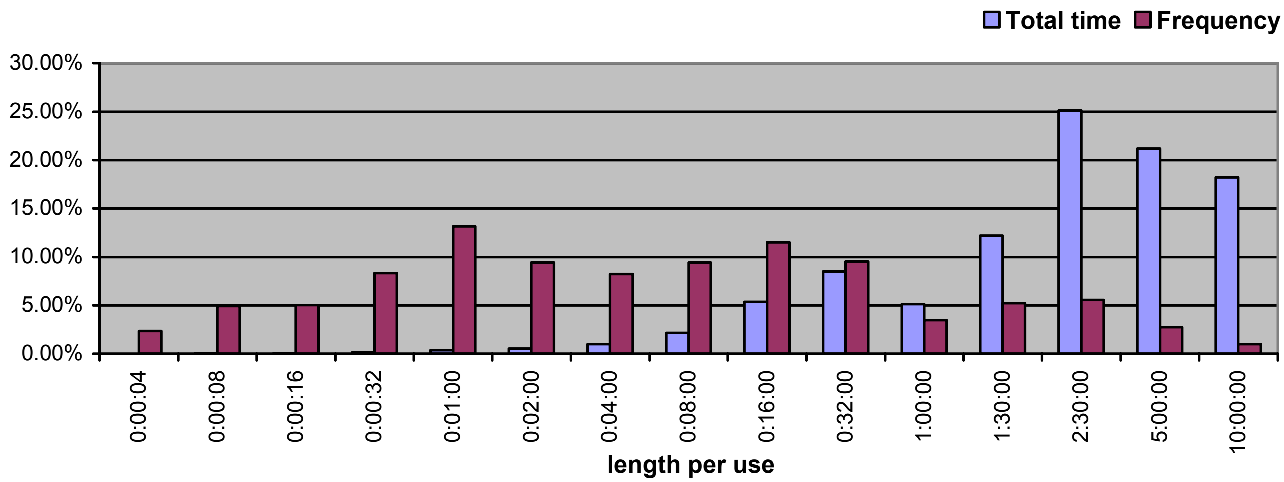

Figure 6. Frequency vs. Energy (Baseline)

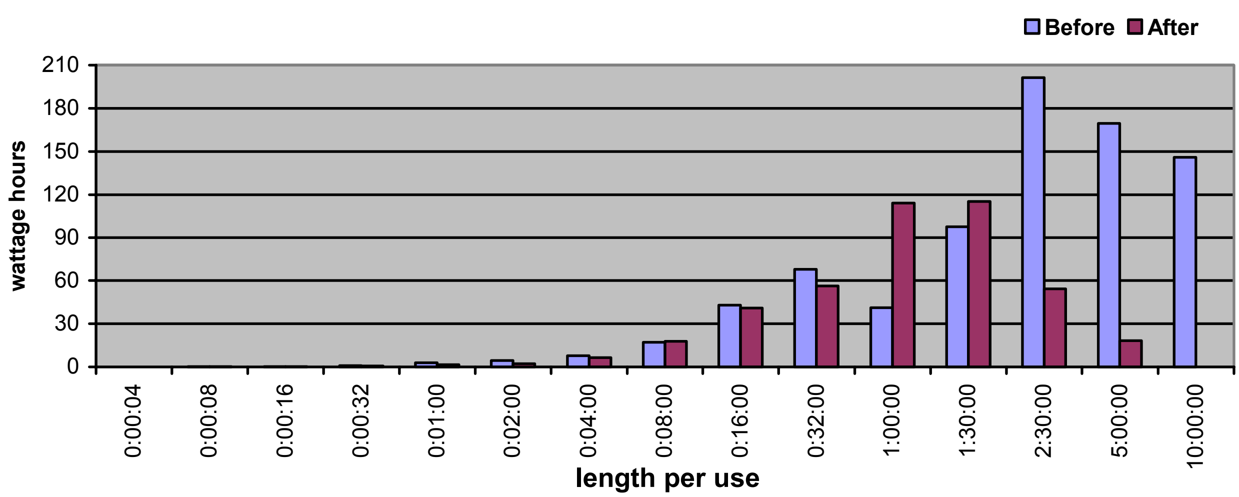

Figure 7. Energy on an average room-day

Figure 7 presents the overall energy savings generated by the LCS. Using the average luminaire power of 180W, Figure 7 shows average room-day energy consumption for both before and after installation of the LCS. For time durations greater than 2.5 hours, the energy savings were significant at 86 percent. The energy consumption between one hour and 2.5 hours increased about 56 percent. The total energy savings were 46.5 percent, which is consistent with the analysis of average burning hours per day.

Discussion

The above analysis provides a great deal of insight into the usage patterns and energy savings at the Sacramento Doubletree Hotel. The next step is to determine how these results relate to the hotel industry as a whole. There are many different types of hotels (business, vacation, conference, etc.) with a variety of baseline conditions that may effect the specific LCS savings at any given site. In this section, several such baseline factors, such as baseline usage and hotel occupancy rates, will be discussed. Finally, a brief discussion of customer feedback is included.

Baseline Conditions

Connected Load

The energy savings produced by the LCS are largely dependent on the load or watts (W) of the existing bathroom luminaire. This can range from under 50 W for a single fluorescent lamp to well over 200 W for an incandescent vanity luminaire. Figure 8 demonstrates what energy reduction is represented by a 46.5 percent reduction in operating hours for luminaires of various wattages. The average load in the rooms at the Doubletree was 180 W, yielding savings of approximately 360 W-hours per day per room. Obviously, larger loads would result in greater energy savings from the LCS, which would produce shorter paybacks for the cost of purchasing and installing the LCS.

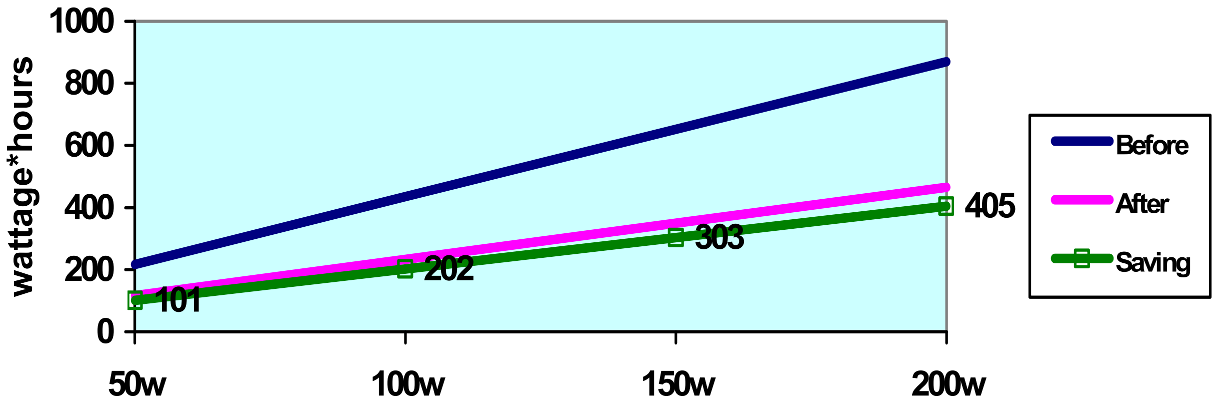

Figure 8. Energy savings for different wattage luminaires

Baseline Hours of Operation

Another variable that has a large effect on the energy savings and payback for the LCS is the baseline hours of operation of the bathroom luminaire. The average of 4.4 hours per day found in this study is significantly lower than that of previous LBNL studies that had found up to eight hours per day at vacation hotels. Hotel industry sources have indicated that these findings are consistent with their experience. Vacation hotels tend to have more occupants spending more time in the hotel rooms that do business hotels. This leads to longer baseline hours of operation for the guestroom luminaires. But this difference in baseline hours is significant, as a doubling of the baseline hours could result in cutting the payback for the LCS in half.

The most accurate method to document LCS energy savings potential in the hotel industry as a whole would be to monitor the usage patterns of many different hotels. Baseline data and post-LCS installation data from each site could be compared to gather averages and trends. As this was not practical for this study, LBNL performed an estimate of the LCS energy savings potential for vacation hotels based on a dataset obtained in a previous study. The discussion is presented below and is not intended to conclusively state what the expected savings in vacation hotels would be. However, it is meant to serve as a first approximation of the potential savings at such sites.

Table 7 shows the process of the estimation. This table includes data from the bin analysis discussed previously in Figure 5, as well as “prior data” from the previous vacation hotel study. The savings potential (column 1) represents the energy savings that the LCS was found to generate for each use period at the Doubletree Hotel. By multiplying this savings potential (column 1) by the baseline energy consumption (column 2) that was found for each bin, the energy savings generated by the LCS can be calculated (column 4). If the assumption is then made that the savings potential (column 1) of the LCS is independent of hotel, then for any hotel in which a breakdown of baseline usage is available, the energy savings can be estimated.

Essentially, this assumption allows for various hotels to have different usage profiles, but calculates the percentage reduction of each of the bins by the introduction of the LCS to match that found at the Doubletree. The energy savings estimate (column 5) of the prior data (column 3) can then be found by multiplying those data by the savings potential (column 1).

This analysis yields the overall result that the energy savings for the current data set is about 46 percent, while for the prior data set it is about 56 percent. This increase in savings is primarily due to the higher percentage of energy consumption by the prior dataset in the five and 10 hour usage bins. This result is noteworthy because not only does the absolute energy savings increase simply because the baseline is larger, but the savings percentage actually increases due to changes in the usage pattern.

Table 7: Energy savings estimate for vacation hotel baseline data set.

Length per use		Savings Potential	Energy consumption percentage before installing the LCS		Energy Savings	
			Current data	Prior data	Current data	Prior data
		(1)	(2)	(3)	(4)=(1)*(2)	(5)=(1)*(3)
Sec	4	18.44%	0.00%	0.00%	0.00%	0.00%
	8	25.52%	0.02%	0.01%	0.00%	0.00%
	16	43.50%	0.04%	0.02%	0.02%	0.01%
	32	35.56%	0.13%	0.07%	0.05%	0.02%
min	1	44.83%	0.38%	0.22%	0.17%	0.10%
	2	46.55%	0.55%	0.41%	0.26%	0.19%
	4	18.01%	1.00%	0.62%	0.18%	0.11%
	8	-4.74%	2.15%	1.37%	-0.10%	-0.07%
	16	4.55%	5.37%	3.51%	0.24%	0.16%
	32	17.29%	8.50%	5.86%	1.47%	1.01%
hour	1	-96.40%	11.85%	10.41%	-11.42%	-10.03%
	2	41.26%	18.29%	14.38%	7.55%	5.93%
	4	92.27%	29.68%	24.62%	27.38%	22.72%
	8	88.00%	11.89%	20.14%	10.46%	17.72%
	16	100.00%	10.14%	18.35%	10.14%	18.35%
Overall					**46.40%**	**56.24%**

LCS Timeout Delay

While the LCS can be programmed with various timeout delays, all of the units used in this study were set to one hour. The effective increase in energy savings from a shorter timeout delay, such as 30 minutes, would be useful to explore. Again, the more accurate method of determining this result would be to monitor a statistically significant number of rooms with shorter timeout delays and compare the results. Unfortunately, this also was not practical during the current study. The data from this study did allow for a first order approximation of increased savings from shorter timeout delays.

A detailed analysis of the data found that decreasing the setpoint to 30 minutes would have only a modest effect on the overall savings of the LCS. This analysis found that, depending on the assumptions made, dropping the setpoint from one hour to 30 minutes would only result in overall energy savings of an additional 1 to 4 percent. Based on this result, it certainly appears that the modest increase in energy savings would not justify the increased hotel guest complaints from increased “false offs” that would be the likely result of changing the LCS timeout delay from one hour to 30 minutes.

Occupancy Rates

The effect of the occupancy rate on the energy savings potential of the LCS was not studied directly. It was determined early in the study that the Doubletree Hotel could not provide LBNL with the desired information on the actual occupancy information for each test room during the test period. Thus, LBNL was required to make the assumption that on the days in which the bathroom light was never used that the room was unoccupied. Because of the uncertainty of this method of estimating occupancy and the desire to maximize the number of data points, the hotel staff were asked to keep the study rooms at an occupancy rate of 100 percent for the duration of the study in order to maximize the number of data points.

The relationship between the occupancy rate and the LCS savings and usage patterns clearly would be useful to know. While the current data set does not contain enough information to fully characterize this relationship, it does provide some clues. Four of the study rooms were kept very near the 100 percent occupancy rate requested, but one of the rooms (room #588) had an occupancy rate near 80 percent for both the baseline and post-LCS periods. Interestingly, room #588 was found to have a larger baseline and a smaller post-LCS period than any of the other four rooms, with energy savings of nearly 70 percent vs. 46.5 percent from the overall average (see Table 6). A closer look at the data from this room suggests that this result may not be a coincidence, but rather the effect of the room's increased vacancy. This is because during the baseline period, the bathroom luminaire will remain in the state in which the guest or housekeeper left it until the room is visited again. Thus, a luminaire that is left on prior to a period of vacancy will generate a very long "on" period. Even if these occurrences are extremely rare, these "super-usages" will have a significant impact on the energy usage of the luminaire. But in the post-LCS period, the super-usages will never occur. This appears to be the difference in room #588. While there are not enough data to calculate the numerical effect of occupancy on the LCS energy savings, data from room #588 give a strong indication that there is such an effect. As the industry average occupancy rate is even lower than that of room #588 (65 percent vs. 80 percent), this remains a very important open question that merits further investigation.

Customer Feedback

The DoubleTree Hotel staff collected informal user feedback on the LCS. Production, placement, collection, tabulation and analysis of a formal user survey placed in the guest rooms was determined to be impractical. Still, significant feedback was obtained from guest interactions with the hotel's customer service representatives and engineering staff. The initial response from hotel guestroom users has been almost uniformly very positive. This is noteworthy because typically the only feedback the hotel staff receives when making changes to the guestrooms is complaints. However, the staff has already received a number of complimentary comments regarding the unit's nightlight feature.

Report Conclusions

As a result of (1) the collaboration established between LBNL, The Watt Stopper Inc., SMUD and the Doubletree Hotel; (2) the LCS units and logging equipment installed at the hotel test site; and (3) the quantitative methodologies described in this report, the LCS was found to significantly reduce energy usage in hotel guestroom bathrooms. The average savings from the LCS measured from this study was found to be 46.5 percent, though this result was likely limited by a number of factors including the hotel's baseline condition and the occupancy rates of the rooms measured.

A conservative estimate of expected savings from the LCS for the hotel industry as a whole is 50 percent. Based on a hotel's current baseline (hours/day), the bathroom luminaire wattage, and the final cost of the LCS, a conservative payback based on 50 percent savings can be easily calculated. The LCS timeout delay of one hour was found to effectively limit long periods of operation without adversely effecting guest comfort. Decreasing the LCS timeout would only slightly increase energy savings, but may adversely effect guest comfort. Overall, guests responded very favorably to the LCS, appreciating the effect of the nightlight.

Customer and Economic Benefits

Customer Benefit

Hotel bathroom lights are often left on all night and are the largest single source of energy usage in the hotel room. Many hotel or institutional bathroom lighting systems are inefficient and the rooms have no nightlights. A WRA Research study found that two out of five travelers leave the bathroom light on at night to serve as a nightlight. An additional 16 percent of travelers bring their own nightlight to the hotel.[2]

According to Sunbeam Hospitality and Andis Company, about 45 percent of all hotel guests leave the bathroom light on while they sleep. That percent is across all segments—economy to luxury, families and singles, men and women.[3] This means that almost half of hotel guests, at a minimum, appear to want some form of night lighting in their hotel room for either convenience or safety reasons. For hotel guests, the LCS product is capability of providing that added benefit.

Economic Benefit

Potential energy cost savings from installing the LCS product in either new construction or retrofit hotel applications is dependent on the wattage of the installed overhead lights and the cost of electricity. The time of use will also affect the savings. For leisure travelers, a greater per day use of bathroom lights is typically seen. For business travelers, per day use of bathroom lights are lower. Although, many hotels may have a mix of leisure and business travelers at any given time.

The cost to install the product is also a consideration. For new construction, the occupancy sensor nightlight would most likely replace a standard switch with a negligible increase in labor. For retrofit applications, an electrician is required with an install time of approximately 30 minutes per switch. O&M costs may be also reduced by some unknown amount as the lower total usage of lights and the decrease in switching will extend the life of lamps installed in the bathrooms.

[2] This data comes from a 1999 survey commissioned by Sleep Inn, the limited service chain franchised by Choice Hotels International. WRA Research, an independent marketing research firm based in Omaha, NE, surveyed 500 Sleep Inn guests in late June regarding their sleeping habits while on the road.

[3] As quoted in Lodging News Global

Considering the above-mentioned variables, quoting one universal simple payback for the LCS product is not practical. However, simple paybacks around 1.5 years have been calculated for new hotels with high wattage bathroom lights in the California area. For retrofit applications (which include the installation cost), the simple payback for hotels with high wattage bathroom lights in the California area extends to 3.2 years. These calculations are based on 240 watts of existing bathroom lighting, 44 percent use of the LCS, and an average energy cost of 15.5 cents per kWh. Incentives to help defray the initial cost of the LCS product may be also available to hotel owners.

The LCS product provides a simple retrofit device for hotel guestrooms to serve the dual purpose of night lighting and occupancy-based lighting control, and provides both energy and non-energy benefits to hotel owners.